Suppression of Wellhead Fires by Use of Water Sprays

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Objective: To develop blowout fire suppression technology for offshore oil and gas operations.

The Center for Fire Research (CFR) of the National Bureau of Standards (NBS) is investigating the feasibility of controlling the radiation from, and the extinguishment of, blowout fires by use of a water spray fire suppression system. It is known that when water is added to hydrocarbon flames, even in small amounts, radiation from the flames is greatly reduced. When sufficiently large quantities of water are added, the flames can be extinguished. The major problem to be overcome is delivering the desired quantity of water and mixing it with the burning hydrocarbons to either control or extinguish the fires.

A series of large-scale tests were conducted in Norman, Oklahoma, to evaluate the performance of a four nozzle water spray configuration (see figure 1). The nozzles were arranged symmetrically about a 4-inch diameter gas outlet to spray water vertically into and around the flame produced

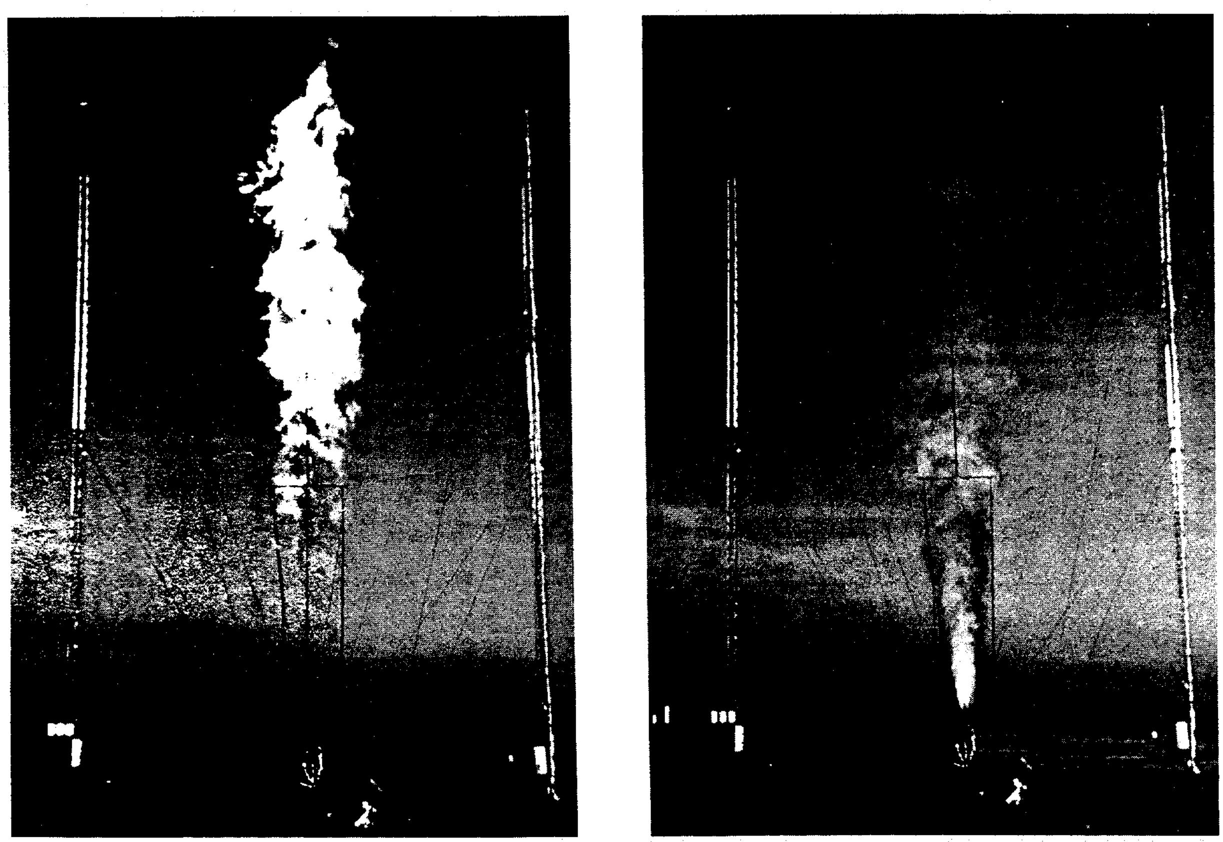

Figure 1.—Jet flame extinguished using only 40 liters of water.
(left) Flame prior to water application.
(right) Flame being extinguished, water flow rate 8.1 liters/second.

Note: Tower height is 24 meters, methane flow rate is 5.6 m^3/s (17 MMSCF/D), fire energy release rate is 200 megawatts.

by burning methane gas. It was found that an unobstructed nominally 200 MW [5.6 m^3/s (17 MMSCF/D*) methane] jet-flame could be extinguished under no wind conditions with a water flow rate of 8.1 liters/s (129 GPM), but would continue to burn with a lower water injection rate of 5.4 liters/s (86 GPM). For scaling purposes extinguishing conditions are specified in terms of the ratio of mass flow rate of water injected to mass flow rate of gas burning. The test results given above indicate that the fire was extinguished at a mass flow rate ratio of 2.17 and failed to be extinguished at a flow rate ratio of 1.56.

Small-scale testing performed at NBS has been used to establish the nominal mass flow rate ratio of water to gas needed to extinguish methane gas fires for four nozzle water spray systems placed at various distances from the gas outlet. Figure 2 shows results from both large and small-scale fires. For the large scale test geometry in which the ratio of the diameter of the ring of four nozzles to the diameter of the gas outlet was 4.5, the flame was extinguished at a water gas mass flow rate ratio of 2.17. Small-scale tests performed with methane flows of 0.28 m^3/s (0.86 MMSCF/D) and a 1.75-inch diameter gas outlet show that the minimum water to gas mass flow rate ratio for extinguishment is 2.15.

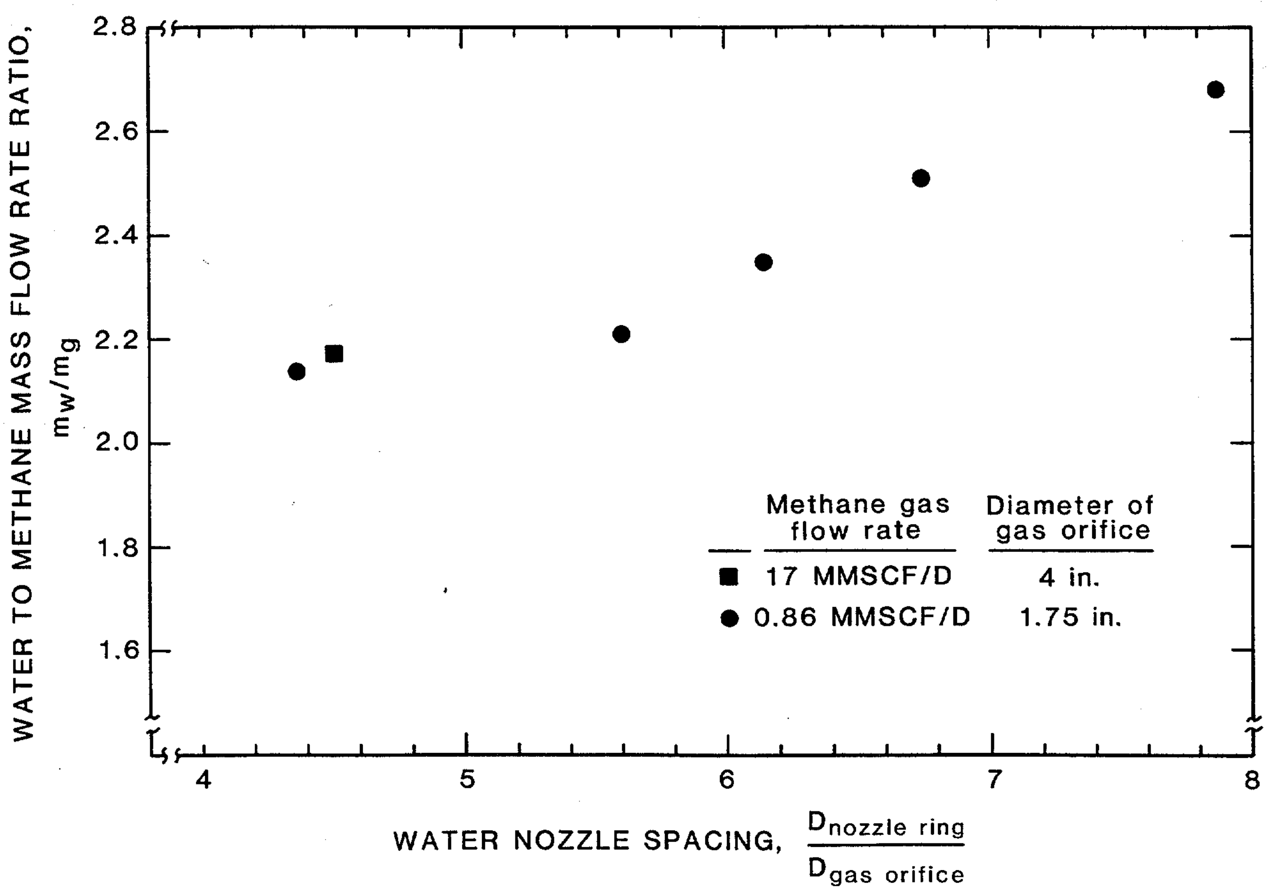

Figure 2.–Sensitivity of methane jet-flame extinguishment to the radial spacing of four water spray nozzles.

*Million standard cubic feet per day.

As shown in figure 2, other small-scale tests run at increased ring diameters show a general increase in water flow rate required for fire extinguishment. Generally a 75 percent increase in nozzle ring diameter requires a 25 percent increase in water flow rate for extinguishment. Other factors, such as spacing between water nozzles along the ring may be a factor at large ring diameters. It is probable that the use of more than four nozzles at larger ring diameters may produce extinguishment of a given fire at lower total water flow rates.

Small-scale tests, placing obstructions in the gas stream, are being conducted to examine the effects on the water flow required to extinguish gas jet flames. It is expected that flames stabilized by obstructions will require larger water to gas mass flow rate ratios to produce extinguishment than those determined to date from testing unobstructed flames. Large-scale tests of water spray extinguishment configurations will be conducted at Louisiana State University where obstruction stabilized fires resulting from methane gas flows of up to 11.5 m^3/s (35 MMSCF/D) can be studied. Results of these tests will be used as the basis for evaluating the possibility of flame extinction and quantification of radiation reduction caused by injection of water spray into a flow.

In addition to flame obstruction difficulties, fundamental work continues on diffusion flame blowoff phenomena (where the flame forms at a distance above the nozzle) and the concept of absolute flame stability. Figure 3, a plot from one of the cited references, shows the stability

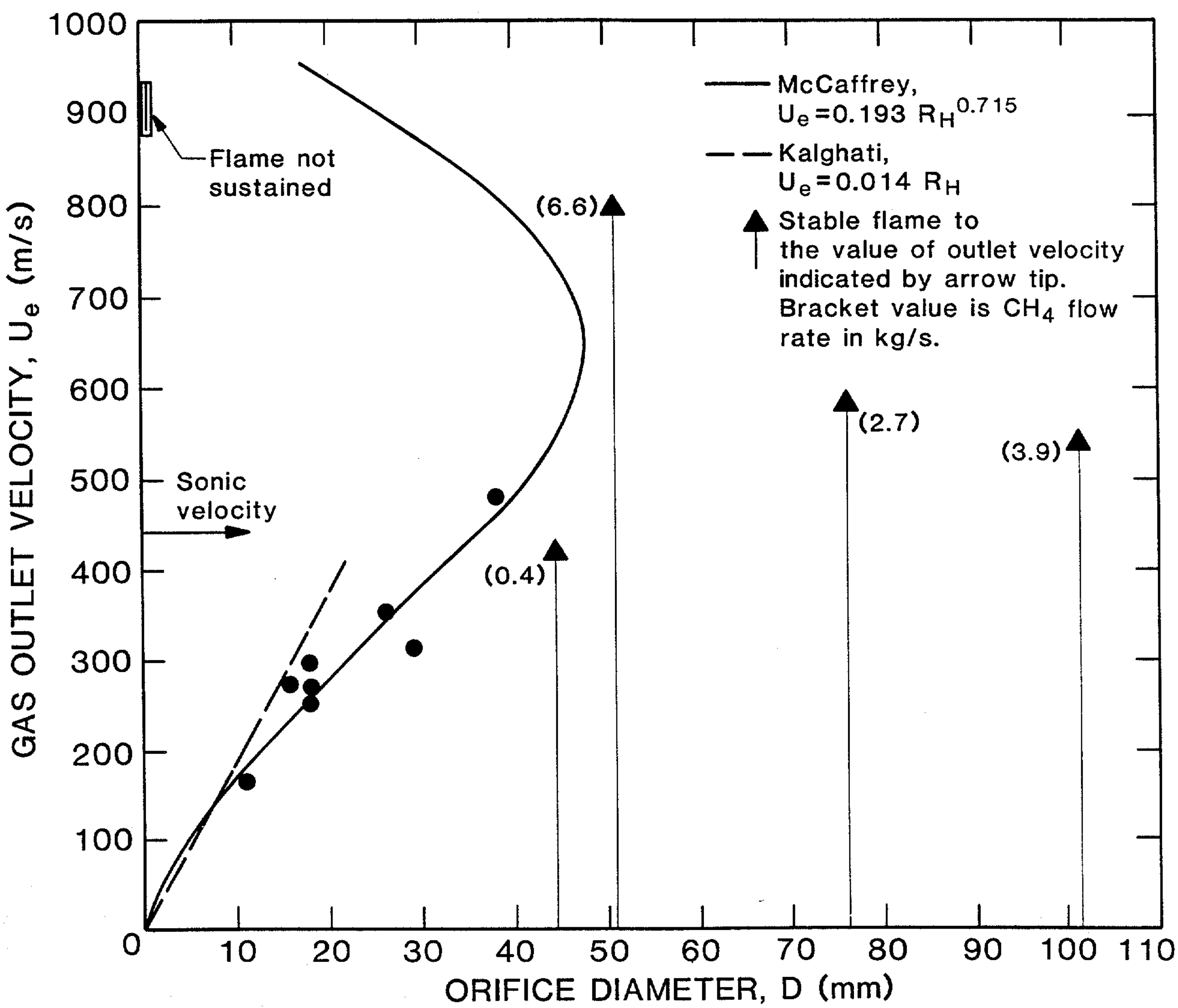

Figure 3.—Stability of jet-flames.

envelope for methane jet flames. The "C"-shaped curve separates stable from unstable flames. Given in terms of a gas outlet velocity (U_e) from a known sized pipe or orifice (D), the dots represent flames which could be blown off with sufficient pressure (when the gas velocity reaches that particular velocity where the flames can no longer be sustained and go out). The curve is a theoretically guided extrapolation of the small diameter test data.

The interpretation is that for an orifice diameter greater than 45-50 mm (2"), flames are absolutely stable irrespective of gas outlet velocities. The upward facing arrows from recent tests at CFR confirm the stability at least up to those velocities. Also for very high velocities and small diameters a new stable regime is predicted to be possible. The approximately 1 mm diameter, 900 m/s point shown on the figure confirms, as expected, based on the extrapolation, only unstable behavior. This does not preclude the existence of an upper stable regime at greater exit velocities. Additional experimentation using greater reservoir pressures is necessary to further evaluate this phenomenon.

References

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